APPENDIX A

Epidemiologic Review

Various investigators have used different occupational epidemiologic methods to identify the patterns of work-related MSD occurrence in different working groups, as well as the factors that influence these disease patterns. The following section briefly summarizes these study designs and then addresses the most common biases (such as misclassification or selection) that can affect the results of these studies.

TYPES OF EPIDEMIOLOGIC STUDY DESIGNS REVIEWED

The NIOSH reviewers have first addressed studies that use a prospective approach. **Prospective cohort studies**, identify groups of subjects (exposed and nonexposed) and observe them over a period of time to compare the number of new work-related MSD cases in the two groups. All subjects are initially disease-free. The rate (or risk) of new cases (the incidence) is calculated for both groups, and the ratio of these two incidences (the relative risk or rate ratio, RR) can be used to assess the association of the exposure with the occurrence of the MSD. A RR greater than 1.0 implies that the incidence of cases was higher in the exposed group than in the nonexposed group and that an association has been observed between the exposure and the disease. A confidence interval (CI) is derived, which is an estimated range of values within which the true RR is likely to fall. The CI reflects the precision of the effect observed in the study. Ordinarily, if the CI includes 1.0, the association between the exposure and the MSD could be due to chance alone and the elevated odds ratio (OR) is not considered statistically significant.

The cohort study ensures that the exposure to work-related factors occurs before the observation of the MSD, thereby allowing a causal interpretation of the observed association. Cohort studies are often done prospectively; they follow a group of current workers forward in time. The length of time required for a prospective study depends on the problem studied. With adverse health conditions that occur as a result of long-term exposure to some factor in the workplace, many years may be needed. Extended time periods make prospective studies costly. Arguing causation is more difficult with extended time periods because other events may affect outcome. Prospective studies that require long periods of time are especially vulnerable to problems associated with worker follow-up, particularly worker attrition (workers discontinue participation in the study) and worker migration (diseased workers move to other employment before investigators ascertain their disease).

The second type of epidemiologic study evaluated for this document is the **case-control study**, which is retrospective and examines differences in exposures among workers with (cases) and without (controls) MSDs. In such studies, cases should be all incident (new) cases in a given population over a defined period or a representative sample of the cases. Controls should be a representative sample of non-cases from the same population. The ratio of the odds of exposed cases to the odds of exposed controls is called the odds ratio (OR). An OR above 1.0 indicates an association between the exposure and the work-related MSD, and a 95% CI indicates the probable range of the true OR. Case control studies are useful for evaluating rarely occurring conditions or small numbers of cases. One limitation of case control studies is the difficulty of obtaining accurate information about past exposures. In occupational studies of MSDs, a further limitation of case-control studies is the difficulty of identifying cases who are representative of all cases that occurred in a defined period (many of these workers will have left the workforce). Another problem with case-control studies is the selection of an inappropriate control group.

Third, the reviewers considered **cross-sectional studies**. Cross-sectional studies provide a "snapshot in time" of a disease process; that is, they measure both health outcomes and exposures at a single point in time. These studies usually identify occupations with differing levels of exposure and compare the prevalences of MSDs in each group. Cross-sectional studies are most useful for identifying risk factors of a relatively frequent disease with a long duration that is often undiagnosed or unreported [Kleinbaum et al. 1982]. Typically, cross-sectional studies do not provide the evidence of the correct temporal relationship between exposure and disease inherent in prospective studies, but they nevertheless can be valuable. Some cross-sectional studies discussed here had inclusion criteria such as working at a specific job for a defined period of time before onset of symptoms. This condition adds a dimension of temporality to the studies. A common problem with cross-sectional studies that use surveys is obtaining sufficiently large response rates; many people who are asked to participate decline because they are busy, not interested, etc. The conclusions are therefore based on a subset of workers who agree to participate, and these workers may not be representative of or similar to the entire population of workers. Furthermore, cross-sectional studies are often confined to current workers who may not be representative of true prevalence rates if workers with disease have left the workforce. (The problem of representativeness is not confined to cross-sectional studies and may occur in the other study designs mentioned whenever subjects are selected, decline, or drop out.) Either ORs or prevalence ratios (PRs) (proportion of diseased in exposed divided by the proportion of diseased in unexposed) may be used to report results in cross-sectional studies.

The last type of observational study used is the **case-series study**, in which certain characteristics of a group (or series) of cases (or patients) are described. The simplest design is a set of case reports for which the author describes some interesting or intriguing observations that occurred in a small number of patients. Cases included in case series have usually been drawn from a single patient population, whose make-up may have influenced the observations noted because of selection bias. Case-series studies frequently lead to a generation of hypotheses that are subsequently investigated in a cross-sectional, case-control, or prospective study. Because case-series do not involve comparison groups (who do not have the condition or exposure to the risk factors being studied), some investigators would not consider them epidemiologic studies because they are generally not planned studies and do not involve any research hypotheses.

BIASES AND OTHER ISSUES IN EPIDEMIOLOGIC STUDIES

In interpreting the validity of epidemiologic studies to provide evidence for work-relatedness of MSDs, several assumptions and sources of bias must be considered when analyzing the findings from such studies.

1. Selection bias (internal validity). In occupational health studies, at least two types of selection bias may occur: (a) a selection of "healthy workers" in the work population studied, and (b) an exclusion of "sick" workers who leave the active workforce. Both of these biases tend to cause an underestimate of the true relationship between a workplace risk factor and an observed health effect because the workers who are in better health tend to be those in the workforce and available for study.

   A basic assumption underlying the analysis of these studies is that the selected cases of work-related MSDs in the specific studies are representative of all workers at that worksite with work-related MSDs. In a single study, representativeness generally increases with increasing population size and participation rate. A parallel assumption is that the nondiseased groups are representative of the entire non-diseased population. The fact that some cases leave the workforce causes the disease prevalence among currently employed workers to be underestimated. However, if cases are missing from the current workforce in equal proportion for both nonexposed and exposed workers, the underestimate of prevalence will not affect the internal validity of the study.

2. Generalizability (external validity). Some studies are based on a single population, occupation, or restricted data base (individual insurance companies, specific industrial settings) and, therefore, the sample may not be representative of the general population. Another assumption is that MSD cases in one study are comparable to cases in another study. This assumption needs particular scrutiny in work-related MSD studies because no standardized case definitions may exist for the particular illnesses.

3. Misclassification bias. Misclassification bias may be introduced during selection of cases and determination of their exposure. Erroneous diagnoses may result in work-related MSD cases misclassified as noncases, and similarly, noncases may be misclassified as cases. The calculated RR or OR would usually underestimate the true association because of a dilutional effect if both exposed and nonexposed cases are equally misclassified. Similarly, misclassification can occur when determining the exposure factor of interest. Again, such misclassification will create a bias towards finding no association if equal misclassification is assumed for cases and noncases.

4. Confounding and effect modification. Other factors may explain the supposed relationship between work and disease. Confounding is a situation in which the relationship (in this case with MSDs) appears stronger or weaker than it truly is as a result of something (the confounder) being associated with both the outcome and the apparent causal factor. In other words, the risk estimate is distorted because symptoms of exposed and nonexposed workers differ because of some other factors that cause disease. For example, diabetes might result in abnormal nerve conduction testing, a sign of CTS. If a higher proportion of exposed workers than nonexposed workers were diabetic, diabetes would act as a positive confounder, causing an apparent exposure-disease association.

   An effect modifier is a factor that alters the effect of exposure on disease. For example, it is possible that repetitive motion causes tendinitis only in older workers; in this case, age would be an effect modifier. Although effect modification is not a bias per se, if an investigator has failed to analyze old and young workers separately, the investigator might have missed a true work/disease association.

5. Sample size, precision, and CIs. The CI around an estimated measure of effect (such as a RR) is an estimated range of values in which the true effect is likely to fall. It reflects the precision of the effect observed in the study. Large studies generally have smaller CIs and can estimate effects more precisely. In studies that are "statistically significant" the CI excludes the null value for no effect (for example, a RR of 1.0). Small studies are generally less precise, lead to wider CIs, and less likely to be "statistically significant" even if the exposed have a greater prevalence of disease than the nonexposed.

APPENDIX B

Individual Factors Associated with Work-Related Musculoskeletal Disorders (MSDs)

Although the purpose of this document purpose is to examine the weight of evidence for the contribution of work factors to MSDs, the multifactoral nature of MSDs requires a discussion of individual factors that have been studied to determine their association with the incidence and prevalence of work-related MSDs. These factors include age [Guo et al. 1995; Biering-Sorensen et al. 1983; English et al. 1995; Ohlsson et al. 1994]; gender [Hales et al. 1994; Johansson 1994; Chiang et al. 1993; Armstrong et al. 1987]; anthropometry [Werner et al. 1994; Nathan et al. 1993, Heliövaara 1987]; and cigarette smoking [Finkelstein 1995; Owen et al. 1984; Svensson et al. 1983; Kelsey et al. 1990; Hildebrandt 1987], among others. Nonoccupational physical activities, such as non-occupational VDT use, hobbies, second jobs, and household activities that might increase risk for MSDs are described in the detailed tables for those studies in which they were analyzed as risk factors.

A worker's ability to respond to external work factors may be modified by his/her own capacity, such as tissue resistance to deformation when exposed to high force demands. The level, duration, and frequency of the loads imposed on tissues, as well as adequacy of recovery time, are critical components in whether increased tolerance (a training or conditioning effect) occurs, or whether reduced capacity occurs which can lead to MSDs. The capacity to perform work varies with gender and age, among workers, and for any worker over time. The relationship of these factors and the resulting risk of injury to the worker is complex and not fully understood.

Certain epidemiologic studies have used statistical methods to take into account the effects of these individual factors (e.g., gender, age, body mass index], that is, to control for their confounding or modifying effects when looking at the strength of work-related factors. Studies that fail to control for the influence of individual factors may either mask or amplify the effects of work-related factors. The comments column of the detailed tables notes whether studies have adjusted for potential confounders.

A number of factors can influence a person's response to risk factors for MSDs in the workplace and elsewhere. Among these are the following:

AGE

The prevalence of MSDs increases as people enter their working years. By the age of 35, most people have had their first episode of back pain [Guo et al. 1995; Chaffin et al. 1979]. Once in their working years (ages 25 to 65), however, the prevalence is relatively consistent [Guo et al. 1995; Biering-Sorensen et al. 1983]. Musculoskeletal impairments are among the most prevalent and symptomatic health problems of middle and old age [Buckwalter et al. 1993]. Nonetheless, age groups with the highest rates of compensable back pain and strains are the 20-24 age group for men, and 30-34 age group for women. In addition to decreases in musculoskeletal function due to the development of age-related degenerative disorders, loss of tissue strength with age may increase the probability or severity of soft tissue damage from a given insult.

Another problem is that advancing age and increasing number of years on the job are usually highly correlated. Age is a true confounder with years of employment, so that these factors must be adjusted for when determining relationship to work. Many of the epidemiologic studies that looked at populations with a wide age variance have controlled for age by statistical methods. Several studies found age to be an important factor associated with MSDs [Guo et al. 1995; Biering-Sorensen et al. 1983; English et al. 1995; Ohlsson et al. 1994; Riihimaki et al. 1989; Toomingas et al. 1991] others have not, [Herberts et al. 1981; Punnett et al. 1985]. Although older workers have been found to have less strength than younger workers, Mathiowetz et al. [1985] demonstrated that hand strength did not decline with aging; average hand pinch and grip scores remained relatively stable in their population with a range of 29 to 59 years. Torell et al. [1988] found no correlation between age and the prevalence of MSDs in a population of shipyard workers. They found a strong relationship between workload (categorized as low, medium, or heavy) and symptoms or diagnosis of MSDs.

Other studies have also reported a lack of increased risk associated with aging. For example, Wilson and Wilson [1957] reported that the age and gender distribution of 88 patients with tenosynovitis from an ironworks closely corresponded to that of the general population of that plant. Similarly, Wisseman and Badger [1976], reported that the median age of workers with chronic hand and wrist injuries in their study was 23 years, while the median age of the unaffected workers was 24 years. Riihimaki et al. [1989] found a significant relationship between sciatica and age in machine operators, carpenters, and sedentary workers. Age was also a strong risk factor for neck and shoulder symptoms in carpenters, machine operators and sedentary workers [Riihimäki et al. 1989]. Some authors may have incorrectly attributed age as the sole cause of their findings in their analysis, when data presented suggested a relationship with work [Schottland et al. 1991].

An explanation for the lack of an observed relationship between an increased risk for MSDs and aging may be "survivor bias" (this is different from the "healthy worker effect"). If workers who have health problems leave their jobs, or change jobs to one with less exposure, the remaining population includes only those workers whose health has not been adversely affected by their jobs. As an example, in a study of female plastics assembly workers, Ohlsson et al. [1989] reported that the degree of increase in the odds of neck and shoulder pain with the duration of employment depended on the age of the worker. For the younger subjects, the odds increased significantly as the duration of employment increased (p=0.01), but for the older ones no statistical change was found with length of employment. The older women who had been employed for shorter periods of time had more reported symptoms than the younger ones, while older workers with longer employment times reported fewer symptoms than younger workers. Ohlsson et al. [1989] interviewed 76 former assembly workers and found that 26% reported pain as the cause of leaving work. This finding supports the likely role of a survivor bias in this study, the effect of which is to underestimate the true risk of developing MSDS, in this case in the older workers.

GENDER

Some studies have found a higher prevalence of some MSDs in women [Bernard et al. 1994; Hales et al. 1994; Johansson 1994; Chiang et al. 1993]. A male to female ratio of 1:3 was described for carpal tunnel syndrome (CTS) in a population study in which occupation was not evaluated [Stevens et al. 1988]. However, in the Silverstein et al. [1985] study of CTS among industrial workers, no gender difference could be seen after controlling for work exposure. Franklin [1991], found no gender difference in workers compensation claims for CTS. Burt et al. [1990] found no gender difference in reporting of neck or upper extremity MSD symptoms among newspaper employees using video display terminals (VDTs). Nathan et al. [1988 and 1992] found no gender differences for CTS. In contrast, Hagberg and Wegman [1987] reported that neck and shoulder muscular pain is more common among females than males, both in the general population and among industrial workers. Whether the gender difference seen with some MSDs in some studies is due to physiological differences or differences in exposure is unclear. One laboratory study, Lindman et al. [1991], found that women have more type I muscle fibers in the trapezius muscle than men, and have hypothesized that myofascial pain originates in these Type I muscle fibers. Ulin et al. [1993] noted that significant gender differences in work posture were related to stature and concluded that the lack of workplace accommodation to the range of workers' height and reach may, in part, account for the apparent gender differences. The reporting bias may exist because women may be more likely to report pain and seek medical treatment than men [Armstrong et al. 1993; Hales et al. 1994]. The fact that more women are employed in hand-intensive jobs and industries may account for the greater number of reported work-related MSDs among women. Bystrom et al. [1995] reported that men were more likely to have deQuervain's disease than women; they attributed this to more frequent use of hand tools. Some studies have reported that workplace risk factors account for increased prevalence of MSDs among women more than personal factors (e.g., Armstrong et al. [1987], McCormack et al. [1990]). In a recent evaluation of Ontario workers compensation claims for "RSI", Asbury et al. [1995] reported a RR for female to male claims ranging from 1.3 to 1.6 across industries. Within 5 different broad occupational categories, females were approximately 2-5 times as likely to have a lost-time RSI claim. No information on gender differences in hand intensive jobs was reported. May researchers have noted that men and women tend to be employed in different jobs.

In order to separate the effect of work risk factors from potential effects that might be attributable to biological differences, researchers must study jobs that men and women perform relatively equally.

SMOKING

Several papers have presented evidence that a positive smoking history is associated with low back pain, sciatica, or intervertebral herniated disc [Finkelstein 1995; Owen et al. 1984; Frymoyer et al. 1983; Svensson et al. 1983; Kelsey et al. 1984]; whereas in others, the relationship was negative [Kelsey et al. 1990; Riihimäki et al. 1989; Frymoyer 1993; Hildebrandt 1987]. Boshuizen et al. [1993] found a relationship between smoking and back pain only in those occupations that required physical exertion. In their study, smoking was more clearly related to pain in the extremities than to pain in the neck or the back. Deyo and Bass [1989] observed that the prevalence of back pain increased with the number of pack-years of cigarette smoking and with the heaviest smoking level. Heliövaara et al. [1991] only observed a relationship in men and women older than 50 years. Two studies did not find a relationship between sciatica and smoking among concrete reinforcement workers and house painters [Heliövaara et al. 1991; Riihimäki et al. 1989].

In the Viikari-Juntura and colleagues' [1994] prospective study of machine operators, carpenters, and office workers, current smoking (OR 1.9 1.0-3.5), was among the predictors for change from "no neck trouble" to "severe neck trouble." In a study of Finnish adults ages 30-64, [Mäkelä et al. 1991], neck pain was found to be significantly associated with current smoking (OR 1.3 CI 1-1.61) when the logistic model was adjusted for age and gender. However, when the model included mental and physical stress at work, obesity, and parity, then smoking (OR 1.25 CI .99-1.57) was no longer statistically significant [Mäkelä et al. 1991]. With univariate analysis, Holmström [1992] found a PRR of 1.2 (CI 1.1-1.3) for neck-shoulder trouble in "current" smokers versus "never" smokers. But using multiple logistic regression, when age, individual and employment factors were in the model, only "never smoked" contributed significantly to neck-shoulder trouble. Toomingas et al. [1991] found no associations between multiple health outcomes (including tension neck, rotator cuff tendinitis, CTS or problems in the neck/scapula or shoulder/upper arm) and nicotine habits among platers, assemblers and white collar workers. In a case/referent study, Wieslander et al. [1989] found that smoking or using snuff was not related to CTS among men operated on for CTS .

Several explanations for the relationship have been postulated. One hypothesis is that back pain is caused by coughing from smoking. Coughing increases the abdominal pressure and intradiscal pressure and puts strain on the spine. A few studies have observed this relationship [Deyo and Bass 1989; Frymoyer et al. 1980; Troup et al. 1987]. The other mechanisms proposed include nicotine-induced diminished blood flow to vulnerable tissues [Frymoyer et al. 1983], and smoking-induced diminished mineral content of bone causing microfractures [Svensson et al. 1983]. Similar associations with diminished blood flow to vulnerable tissues have been found between smoking and Raynaud's disease.

PHYSICAL ACTIVITY

The relationship of physical activity and MSDs is more complicated than just "cause and effect." Physical activity may cause injury. However, the lack of physical activity may increase susceptibility to injury, and after injury, the threshold for further injury is reduced. In construction workers, more frequent leisure time was related to healthy lower backs [Holmstöm et al. 1993] and severe low back pain was related to less leisure time activity [Holmstöm et al. 1992]. On the other hand, some standard treatment regimes have found that musculoskeletal symptoms are often relieved by physical activity. Having good physical condition may not protect workers from risk of MSDs. Garg [1989] stated that persons with high aerobic capacity may be fit for jobs that require high oxygen uptake, but will not necessarily be fit for jobs that require high static and dynamic strengths and vice versa.

When physical fitness is examined as a risk factor for MSDs, results are mixed. For example, some early case series reported an increased risk of MSDs associated with playing professional sports [Bennet 1946; Nirschl 1993], or with physical fitness and exercise [Kelsy et al. 1975; Dehlin et al. 1978, 1981] while other studies indicate a protective effect and reduced risk [Cady et al. 1979; Mayer et al. 1985; Astrand et al. 1987; Biering-Sorensen et al. 1984]. Boyce et al. [1991] reported that only 7% of absenteeism could be explained by age, sex, and physical fitness among 514 police officers 35 years or older. Cady et al. [1979, 1985], on the other hand, found that physical capacity was related to musculoskeletal fitness. Cady defined fitness for most physical activities as combinations of strength, endurance, flexibility, musculoskeletal timing and coordination. Cady et al. [1979] evaluated male fire fighters and concluded that physical fitness and conditioning had significant preventive effects on back injuries (least fit 7.1% injured, moderately fit 3.2% injured and most fit 0.8% injured). However, the most fit group had the most severe back injuries. Low cardiovascular fitness level was a risk factor for disabling back pain in a prospective longitudinal study among aerospace manufacturing workers by Battie et al. [1989]. Good endurance of back muscles was found to be associated with low occurrence of low back pain [Biering-Sorensen et al. 1984].

Few occupational epidemiologic studies have looked at non-work-related physical activity in the upper extremities. Most NIOSH studies [Hales and Fine 1989; Kiken et al. 1990; Burt et al. 1990; Baron et al. 1991; Hales et al. 1994; Bernard et al. 1994] have excluded MSDs due to sports injury or other non-work-related activity or injury and have not included these factors in analyses. However, many of the risk factors that are important in occupational studies occur in sports activities--forceful, repetitive movements with awkward postures. A combination of high exposure to load lifting and high exposure to sports activities that engage the arm was a risk factor for shoulder tendinitis, as well as osteoarthritis of the acromioclavicular joint [Stenlund et al. 1993]. Kennedy et al. [1978] found that 15% of competitive swimmers with repetitive overhead arm movements had significant shoulder disability primarily due to impingement from executing butterfly and freestyle strokes. Hill [1983] estimated that 10% of baseball pitchers experienced shoulder tendinitis. Epicondylitis in professional athletes has been well documented, and many of the biomechanical and physiological studies of epicondylitis have been conducted in professional tennis players and baseball pitchers [King et al. 1969; Nirschl 1993]. One prospective study of healthy baseball players has found slowing of the suprascapular nerve function as the season progresses [Ringel et al. 1990]. Scott and Gijsbers [1981] found an association between athletic performance and pain tolerance, and suggested that physically fit persons may have a higher threshold for injury.

In summary, although physical fitness and activity is generally accepted as a way of reducing work-related MSDs, the present epidemiologic literature does not give such a clear indication. The sports medicine literature, however, does give a better indication that sports involving activities of a forceful, repetitive nature (such as tennis and baseball pitching) are related to MSDs. It is important to note that professional sports activities usually provide players (i.e., workers) with more substantial breaks for recovery and shorter durations for intense tasks as compared with more traditional work settings in which workers are required to perform repetitive, forceful work for 8 hours per day, 5 days per week.

STRENGTH

Some epidemiologic support exists for the relationship between back injury and a mismatch of physical strength and job tasks. Chaffin and Park [1973] found a sharp increase in back injury rates in subjects performing jobs requiring strength that was greater or equal to their isometric strength-test values. The risk was three times greater in the weaker subjects. In a second longitudinal study, Chaffin et al. [1977] evaluated the risk of back injuries and strength and found the risk to be three times greater in the weaker subjects. Keyserling et al. [1980] strength-tested subjects, biomechanically analyzed jobs, and assigned subjects to either stressed or non-stressed jobs. Following medical records for a year, they found that job matching based on strength criteria appeared to be beneficial. In another prospective study, Troup et al. [1981] found that reduced strength of back flexor muscles was a consistent predictor of recurrent or persistent back pain, but this association was not found for first time occurrence of back pain.

Other studies have not found the same relationship with physical strength. Two prospective studies of low back pain reports (or claims) of large populations of blue collar workers [Battie et al. 1987, 1989; Leino 1987] failed to demonstrate that stronger (defined by isometric lifting strength) workers are at lower risk for low back pain claims or episodes. One study followed workers for ten years after strength testing and the other followed workers for a few years. Neither of these studies included precise measurement of exposure level for each worker, so the authors could not estimate the degree of mismatch between workers' strength and tasks demands. Battie compared workers with back pain with other workers on the same job (by isometric strength testing) and did not find that workers with back pain were weaker. In two studies of nurses [Videman 1989; Mostardi 1992] lifting strength was not a reliable predictor of back pain.

When examined together, these studies reveal the following: The studies that found a significant relationship between strength/job task and back pain used more thorough job assessment or analysis and have focused on manual lifting jobs. However, these studies only followed workers for a period of one year, and whether this same relationship would hold over a much longer working period remains unclear. Studies that did not find a relationship, although they followed workers for a longer period of time, did not include precise measurements of exposure level for each worker, so they could not assess the strength capabilities that were important in the individual jobs. Therefore, they could not estimate the degree of mismatch between workers' strength and task demands.

ANTHROPOMETRY

Weight, height, body mass index (BMI) (a ratio of weight to height squared), and obesity have all been identified in studies as potential risk factors for certain MSDs, especially CTS and lumbar disc herniation.

Few studies examining anthropometric risk factors in relationship to CTS have been occupational epidemiologic studies; most have used hospital-based populations who may differ substantially from working populations. Nathan et al. [1989, 1992, 1994] have published several papers on the basis of a single industrial population and have reported an association between CTS and obesity; however, the methods employed in their studies have been questioned in a number of subsequent publications [Letz and Gerr 1992; Stock 1991; Werner et al. 1994]. Several investigators have reported that their industrial study subjects with CTS were shorter and heavier than the general population [Cannon et al. 1982; Dieck and Kelsey 1985; Falk and Aarnio 1983; Nathan et al. 1992; Werner et al. 1994; Wieslander et al. 1989]. In the Werner et al. [1994] study of a clinical population requiring electrodiagnostic evaluation of the right upper extremity, patients classified as obese (BMI>29) were 2.5 times more likely than slender patients (BMI<20) to be diagnosed with CTS. Werner et al. [1994] developed a multiple linear regression CTS model (with the difference between median and ulnar sensory latencies as the dependent variable) that demonstrated that BMI was the most influential variable, but still only accounted for 5% of the variance in the model. In Nathan's [1994] logistic model, body mass index accounted for 8.6% of the total risk; however, this analysis used both hands from each study subject as separate observations, although they are not independent of each other. Falk and Aarnio [1983] found no difference in BMI among 17 butchers with (53%) and without (47%) CTS. Vessey et al. [1990] found that the risk for CTS among obese women was double for that of slender women. The relationship of CTS and BMI has been suggested to relate to increased fatty tissue within the carpal canal or to increased hydrostatic pressure throughout the carpal canal in obese persons compared with slender persons [Werner 1994].

Carpal tunnel canal size and wrist size has been suggested as a risk factor for CTS, however, some studies have linked both small and large canal areas to CTS [Bleecker et al. 1985; Winn and Habes 1990].

For back MSDs, Hubrec and Nashold [1975] found that height and weight were predictive of herniated disc disease among World War II U.S. army recruits compared with age-matched controls. Some studies have reported that people with back pain, are, on the average, taller than those without it [Rowe et al. 1965; Tauber et al. 1970; Merriam et al. 1983; Biering-Sorensen et al. 1983]. Heliövaara et al. [1987], in a Finnish population study, found that height was a significant predictor of herniated lumber disc in both sexes, but a moderately increased BMI was predictive only in men. Severe obesity (exceeding 30 kg/m^2) involved less risk than moderate obesity. Kelsey [1975] and Kelsey et al. [1984], failed to reveal any such relationships between height or BMI among patients with herniated lumber discs and control subjects. Magora and Schwartz [1978], found an association between obesity and radiological disc degeneration, but Kellgren and Lawrence [1958] did not. A study of Finnish white collar and blue collar workers found no association between overweight (relative weight (> 120%) and lumbosacral disorders either cross-sectionally or in a 10 year follow-up [Aro and Leino 1985].

Schierhout et al. [1995] found that short stature was significantly associated with pain in the neck and shoulder among workers in 11 factories, but not in the back, forearm, hand and wrist. Height was not a factor for neck, shoulder or hand and wrist MSDs among newspaper employees [Bernard et al. 1994]. Kvarnstrom [1983] found no relationship between neck/shoulder MSDs and body height in a Swedish engineering company with over 11,000 workers.

Anthropometric data are conflicting, but in general indicate that there is no strong correlation between stature, body weight, body build and low back pain. Obesity seems to play a small but significant role in the occurrence of CTS.